PUBLIC REVIEW DRAFT

Appendix 1

Proposed Site-Specific Dissolved Oxygen Objective for the Klamath River in California

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1.0 Introduction

The purpose of this appendix is to present the North Coast Regional Water Quality Control Board (Regional Water Board) staff's scientific justification for a proposed site-specific dissolved oxygen (DO) objective for the Klamath River in California. The appropriateness of the existing DO objective for the Klamath River is assessed in order to determine what revisions and/or updates are required to ensure full protection of water quality and beneficial uses. To this end, staff evaluated four lines of evidence regarding the appropriateness of the existing DO objectives for the Klamath River mainstem presented in Table 3-1 of the *Water Quality Control Plan for the North Coast Region* (Basin Plan). Staff further considered three alternatives to the existing objectives, and proposed one alternative as a new site-specific DO objective for the Klamath River in California. The Klamath River TMDLs have been developed to comply with the proposed site-specific DO objective for the Klamath River in California.

1.1 Assessment of Background Dissolved Oxygen Objectives

The framework of the Basin Plan is based on the logic that protection of water quality in the North Coast is best provided by prohibiting the point source discharge of waste. Some exceptions to this framework are included in the Basin Plan for the Lost River and for the Mad, Eel, and Russian Rivers from October 1 through May 14. In all other streams and all other times of the year, the point source discharge of waste is prohibited, with individual exceptions granted by the Regional Water Board.

The DO objectives included in the Basin Plan compliment this framework by requiring that for all the streams named in Table 3-1 of the Basin Plan, background ambient water quality conditions for DO be maintained. To accomplish this end, the Table 3-1 DO objectives are established at background levels as measured in the 1950s and 1960s. For those waterbodies not named in Table 3-1 of the Basin Plan, DO objectives designed to protect aquatic fish and wildlife resources (i.e., life cycle DO objectives) apply.

For the Klamath River, numeric objectives are assigned in Table 3-1 of the Basin Plan for the following hydrologic areas: 1) upstream of the Iron Gate Dam, 2) downstream of Iron Gate Dam, 3) on tributaries of the Middle Klamath River, and 4) on tributaries of the Lower Klamath River. The Klamath River DO impairment applies only to the mainstem of the Klamath River.

Upstream of the Iron Gate Dam, the instantaneous minimum concentration of DO required is 7.0 mg/L. Half of the monthly mean DO values for the year must be 10.0 mg/L or greater.

Downstream of the Iron Gate Dam, the instantaneous minimum concentration of DO required is 8.0 mg/L. Half of the monthly mean DO values for the year must also be 10.0 mg/L or greater.

Staff has assessed the Table 3-1 DO objectives for the Klamath River mainstem to determine if they are appropriate for the protection of beneficial uses in those reaches. The assessment highlights several lines of evidence indicating that the Table 3-1 DO objectives for the Klamath River mainstem do not depict true background conditions and are unachievable using modern monitoring equipment.

The Table 3-1 DO objectives were developed for individually named waterbodies throughout the Region and include 58 separate entries. They are based on data collected in the 1950s and 1960s by a range of partners including federal, state and local agencies. The Department of Water Resources published the data in annual bulletins beginning with data from 1951. Generally, the data are monthly grab samples that were collected during daylight hours and analyzed in the field using the Winkler titration method.

1.1.1 Grab Sampling versus Continuous Monitoring

The first line of evidence that the Table 3-1 DO objectives require updating is based on the relationship between grab samples and the diel fluctuation of DO in many freshwater systems. DO fluctuates temporally and spatially as a result of numerous factors, including both natural and anthropogenic factors. A grab sample provides only a snapshot of the DO condition at that location at a given moment in time.

For the period of time when ambient water quality data was routinely collected during daylight hours by grab, the results could reasonably be compared to the Table 3-1 objectives for compliance and other purposes. This is because the Table 3-1 objectives were developed from data collected in the same manner. However, Regional Water Board staff more recently began collecting ambient DO data using continuous monitoring probes (datasondes). These datasondes collect data at a preset interval over the course of a day or longer and electronically record the results. The outcome is a continuous DO dataset that shows the pattern and range of DO fluctuation over the course of 24 hours, including the minimum DO condition generally observed during the night.

Summers and Engle (1993), as cited by SCCWRP (2003), found that single, daytime instantaneous measures of DO detected hypoxia[1] only 20% of the time that it was known to occur based on 31 days of continuous sampling in the Gulf of Mexico. While this statistic is unlikely to apply to freshwater streams in the North Coast, it nonetheless illustrates the point that minimum objectives based on data collected during the day can not reasonably represent true daily minimums which are more typically experienced at night.

1.1.2 Historic Land Use

The second line of evidence that the Table 3-1 DO objectives require updating is based on the history of land use in the North Coast Region prior to and including the period of the 1950s and 1960s. Commercial scale mining and logging operations began in areas throughout California, including the North Coast Region in the mid- to late 1800s. This was followed by dam building and agricultural enterprises, as well as urban development. By the 1950s and 1960s, areas of the North Coast Region were undergoing their second wave of timber cutting; by that time with the use of tractors and other heavy equipment, leaving a significant foot print on the landscape and downstream watercourses. Though

[1] Hypoxia means "low oxygen." In estuaries, lakes, and coastal waters low oxygen usually means a concentration of less than 2 parts per million. In many cases hypoxic waters do not have enough oxygen to support fish and other aquatic animals.

the point source discharge of waste from urban development has been very localized in the North Coast Region, other direct effects on water quality from stream channel modification, road building, dam building, and gravel mining, as examples, have been felt in the North Coast Region for over a century. Further, the indirect effects of nonpoint source pollution emanating from agricultural runoff, wetland reclamation, sedimentation, water diversions, and the like have also been felt in the North Coast for over a century.

The National Research Council, in its assessment of the causes of decline in salmonid populations in the Klamath River watershed, describes the history of land use as the primary factor affecting the decline in the fisheries (NRC 2004). In summary they conclude that

> "The watershed has been drastically altered by human activities. The anadromous fishes have been in decline since the 19th century, when dams, mining, and logging severely altered many important streams and shut off access to the upper basin. The declines continued through the 20th century with the development of intensive agriculture and its accompanying dams, diversion, and warm water (NRC 2004)."

As such, DO data collected during the 1950s and 1960s necessarily reflect conditions altered from natural background, influenced by increases in sedimentation, increases in nutrient and organic loading, losses of riparian vegetation and shading, and increases in stream temperatures and reduces flows as the result of diversion of water and consumptive use for agriculture. As a result, though identified as "background," the water quality objectives contained in Table 3-1 for DO do not represent *natural* background conditions, but background conditions altered by anthropogenic influences.

1.1.3 Dissolved Oxygen at Saturation

The third line of evidence that the Table 3-1 DO objectives require updating is derived from an assessment of DO saturation in the Klamath River mainstem. In a healthy riverine system, fully saturated conditions occur in the absence of moderating influences such as waterfalls, algal growth, or significant decomposition of organic material. For a given location, full saturation (100%) is calculated based on the temperature, barometric pressure, and salinity. DO is not expected to exceed 100% saturation except in the immediate vicinity of turbulent water or as a result of significant aquatic plant photosynthesis. Staff calculated 100% and 85% saturation values for the Klamath River using maximum and minimum barometric pressures recorded at Klamath Glen and Yreka. Eighty-five percent saturation is an estimate, as described below, of the minimum values resulting from variation in saturation that could occur within a healthy, free-flowing river as a result of normal photosynthetic activity and decomposition.

Figure 1 illustrates that even at 100% saturation, DO is less than 8 mg/L (the existing DO objective for the Klamath River downstream of Iron Gate Dam) as temperatures exceed 21°C, a condition which occurs in the Klamath River even under natural temperatures during the summer. Figure 2 illustrates that allowing for normal variation from full saturation due to photosynthesis and decomposition (estimated as 85% saturation), there

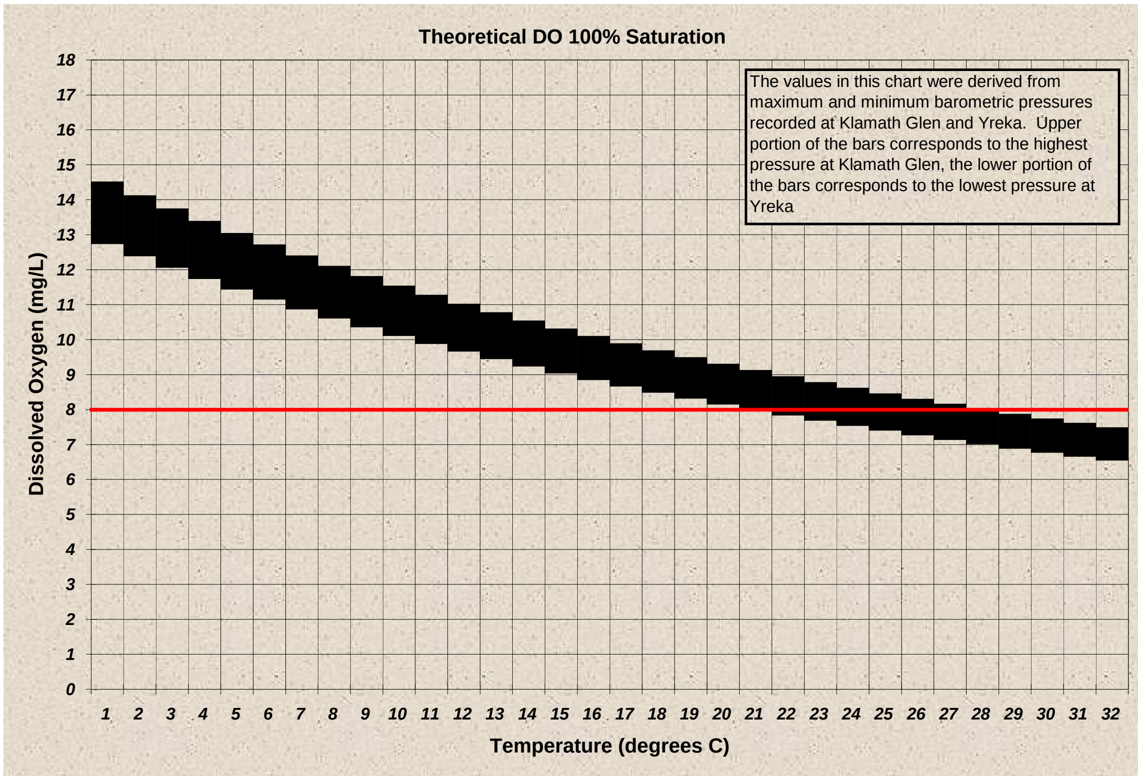

Figure 1: Theoretical Dissolved Oxygen Concentrations at 100% Saturation

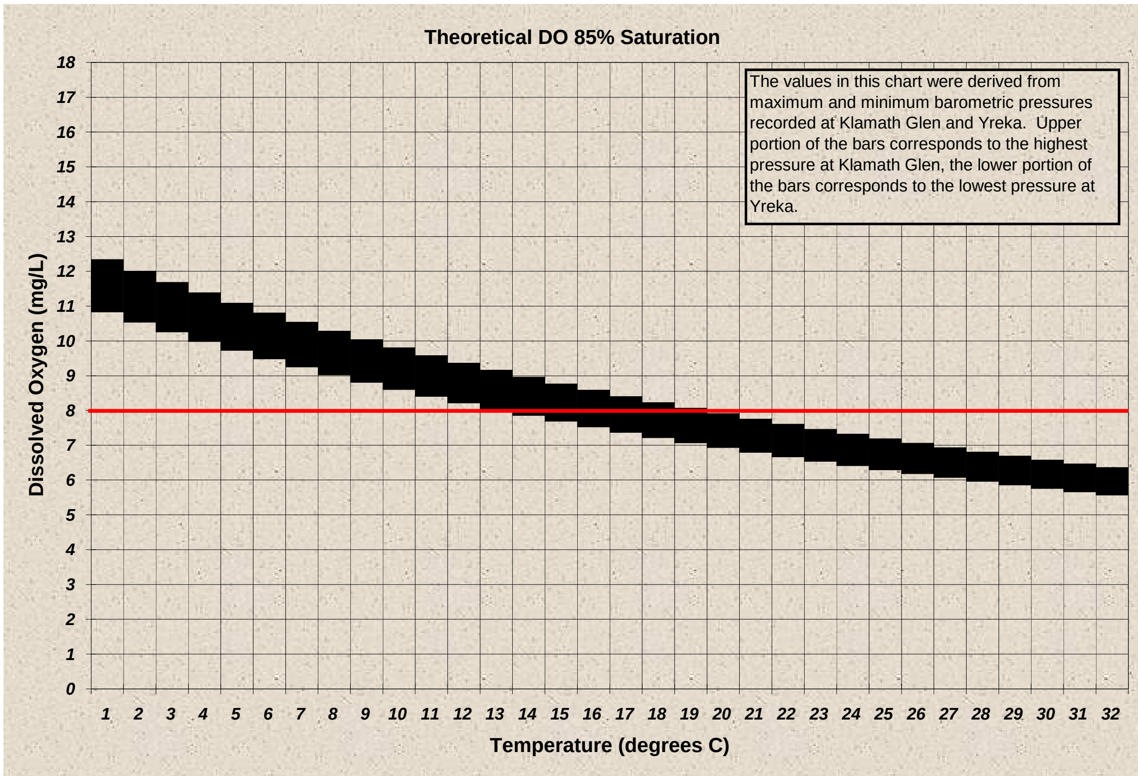

Figure 2: Theoretical Dissolved Oxygen Concentrations at 85% Saturation

are numerous places and times throughout the Klamath River mainstem in which achieving 8 mg/L DO is physically impossible.

1.1.4 Klamath River TMDL for Dissolved Oxygen

The fourth line of evidence that the Table 3-1 DO objectives require updating is based on the Klamath River TMDL modeling. The DO results of the model simulation of natural conditions baseline (see Staff Report Section 3.3.2) are expressed as hourly measures of DO at key locations throughout the Klamath River mainstem. Upon plotting the simulated data for individual sites, TMDL staff determined that the natural conditions baseline scenario indicated periods of noncompliance with the existing Table 3-1 background DO objectives. Figure 3 illustrates the hourly fluctuations of simulated DO throughout the year downstream of Iron Gate Dam under the natural conditions baseline scenario as compared to the 8.0 mg/L DO objective currently applicable at that site. Figure 3 shows that when the river is modeled without anthropogenic influences (e.g., dams, point source discharges, and non-point source discharges) DO is regularly less than 8.0 mg/L for some portion of the time between the months of June and September. This corresponds to the upper portion of the bars on Figures 1 and 2.

Figure 3: Natural Conditions Baseline Scenario Dissolved Oxygen Concentrations at the Klamath River Below Iron Gate Dam Location

1.2 Revised Dissolved Oxygen Objective Alternatives for the Klamath River Mainstem

The evidence above has led Regional Water Board staff to identify alternatives for the revision of the existing DO objectives for the Klamath River. Staff has considered three possible alternatives.

1. Establish DO objectives based on USEPA's guidance for establishing dissolved oxygen criteria (USEPA 1986).
2. Establish DO objectives based on the Klamath River TMDL model output representing natural conditions (T1BSR).
3. Establish DO objectives based on DO saturation at natural temperatures.

1.2.1 Alternative 1: USEPA Guidance

USEPA (1986) provides guidance on the development of DO criteria designed to protect beneficial uses. In the case of cold water streams, like the Klamath River, salmonids are identified as the most sensitive organisms. To assess this alternative, staff identified a set of DO criteria derived from USEPA (1986) and designed to protect the life cycle requirements of salmonids. These criteria are for comparison purposes only, though the daily minimum objectives are identical to the existing life cycle based objectives contained in the Basin Plan: 1) COLD, 6.0 mg/L as a daily minimum and 8.0 mg/L as a 7-day average and 2) SPWN, 9.0 as a daily minimum and 11.0 mg/L as a 7-day average.

Figure 4 compares the natural conditions baseline scenario model output to the USEPA (1986) life cycle based objectives. It shows that in the absence of anthropogenic influences (e.g., dams, point source discharges, and non-point source discharges) simulated ambient water quality conditions achieve the daily minimum DO requirements for cold water fish (6.0 mg/L) throughout the year. It is during the spawning season (including early development), estimated to last from September 15 through June 4[2], that simulated water quality conditions do not appear consistently to meet the life cycle requirements (9.0 mg/L during spawning, egg incubation, and early development). During the first couple of weeks of the spawning season (e.g., estimated as September 15 through September 30), simulated DO at most of the stations is less than 9.0 mg/L. But, it varies from 9.0 mg/L by less than 1 mg/L (≥8.0 mg/L). Similarly, simulated DO at stations from the state line and to the confluence with the Scott River begins to decrease below 9.0 mg/L in April and downstream of the Scott River beginning in May. Again, the variance from 9.0 mg/L is generally no more than 1 mg/L (≥8.0 mg/L) through the spawning season ending in early June.

More dramatic, however, is the comparison of simulated natural background DO conditions to 7-day moving average life cycle requirements, specifically the spawning requirements (Figure 5). In this comparison, simulated ambient water quality does not meet the 11.0 mg/L 7-day average at individual stations for 3-6 months of the 7 ½ month

[2] According to Moyle (2002), salmonid spawning and incubation generally occurs in the North Coast Region from mid-September to early June. The Hoopa Valley Tribe has established in its water quality control plan a spawning and incubation period of September 15 through June 4 based on studies in the Trinity River. To remain consistent, the period of September 15 through June 4 is used for the purpose of this assessment.

period in which it should apply, depending on the station. As a general matter, the weekly average DO appears to reach a peak in November, plateau through early January and then begin to steadily decrease until reaching a low in late July/early August. Weekly average DO then begins to increase again until reaching a peak in late October. The increases and decreases in seasonal DO appear to be primarily a function of temperature.

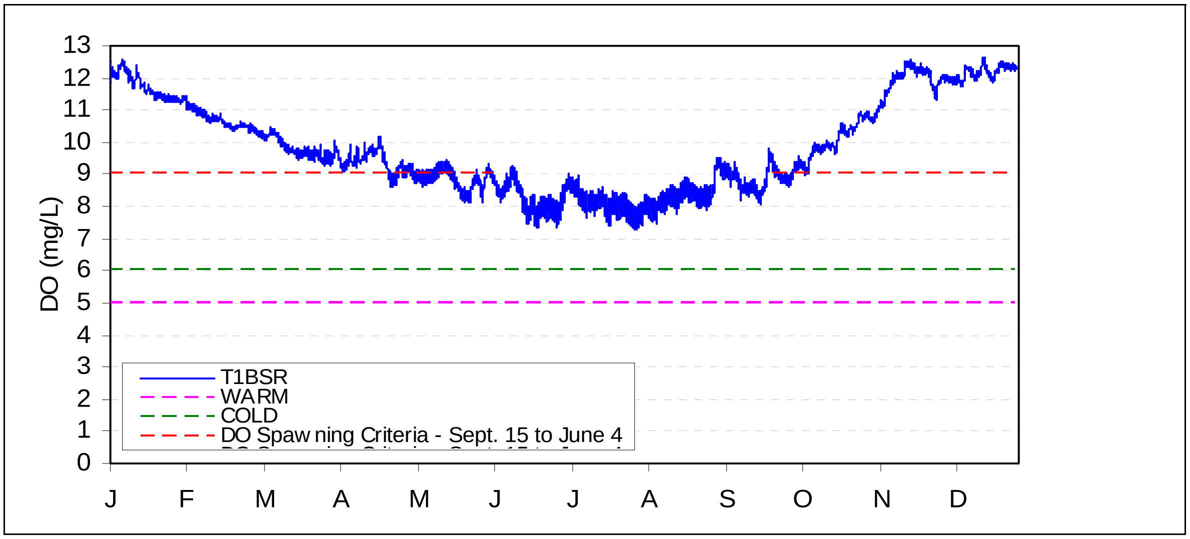

Figure 4: Estimated daily minimum DO under natural conditions (TIBSR) as compared to proposed life cycle requirements: Downstream of Iron Gate Dam on the Klamath River

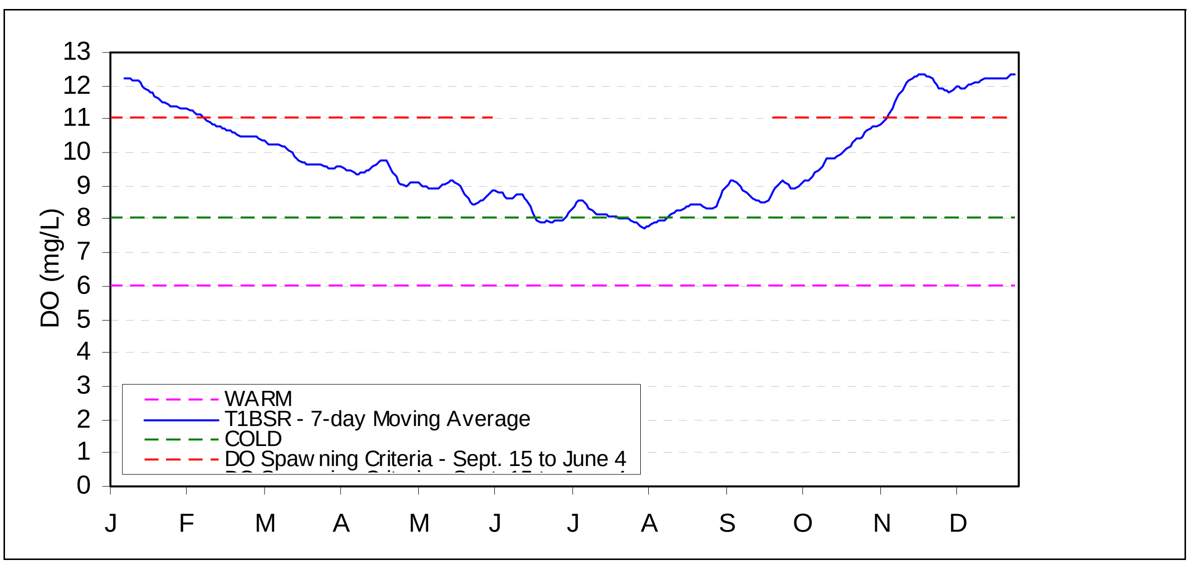

Figure 5: Estimated 7-day average DO under natural conditions (T1BSR) as compared to proposed life cycle requirements: Downstream of Iron Gate Dam on the Klamath River

The comparison of estimated natural conditions baseline to derived life cycle based criteria suggests that the Klamath River mainstem has not historically produced ideal DO conditions for salmonids. Yet, the Klamath River has historically had large runs of anadromous fishes with diverse life histories (NRC 2004). Coho salmon, spring-run Chinook salmon and summer steelhead in particular have historically depended heavily on the Klamath River tributaries to complete their life cycles and sustain their populations (NRC 2004). One hypothesis is that their large dependence on higher quality tributary conditions may have ensured their success in the basin until the degradation of tributary conditions was well underway. Staff concludes that establishing DO objectives based on salmonid life cycle requirements is not appropriate for the Klamath mainstem. But, the protection of DO and temperature refugia in the mainstem and tributaries will be paramount to the protection of the basin's salmonids.

1.2.2 Alternative 2: Klamath River TMDL Model Natural Conditions Baseline Scenario Output

The Klamath TMDL model natural conditions baseline scenario provides an estimate of the DO conditions in the Klamath River mainstem under natural conditions (see Staff Report Section 3.3.2). The natural conditions baseline scenario output indicates a typical pattern in which DO is high in the winter months with little daily fluctuation, decreases during the spring months, reaches its lowest level in the summer with large daily variation, and rises again over the fall.

To derive candidate water quality objectives from the natural conditions baseline model output, staff first identified the daily minimum and monthly mean values at each of the modeled locations on the Klamath mainstem. These are reported in Table 1 as "Natural Background," including the 50% and 90% lower limit of monthly means in a 12 month period. Then, because the natural conditions baseline scenario provides an estimate of DO conditions under a single set of parameters, staff identified a correction factor suitable to account for natural variation in DO conditions, as well as incidental and/or uncontrollable anthropogenic effects. These factors are implicitly included in the existing Table 3-1 DO objectives because those objectives are based on data collected during the 1950s and 1960s when weather conditions varied widely and anthropogenic influences were experienced throughout the basin.

To develop an appropriate correction factor, staff reviewed the Basin Plan to determine the variance from natural background that is allowed for other parameters. Water quality objectives for turbidity, pH, temperature and DO for ocean waters are based on natural conditions, allowing for minor variance. For example, the Basin Plan requires that:

1. Turbidity remain within 20% of naturally occurring background levels;
2. Changes in normal ambient pH levels not exceed 0.5 units, or 6-7% of background;
3. The temperature of cold water streams not be increased by more than 5 °F above natural receiving water temperature, or 6-15% of background; and,
4. The DO in ocean waters not be depressed more than 10% from that which occurs naturally.

Based on these findings, staff applied a 10% correction factor to the modeled estimates of natural background to derive an alternative concentration-based DO objective to the objectives currently contained in Table 3-1 of the Basin Plan. These are reported in Table 1 as "Alternative Objective."

Table 1: Alternative DO Objectives for the Klamath River Mainstem

Waterbody Reach	Daily minimum (mg/L)		90% lower limit (mg/L)		50% lower limit (mg/L)	
	Natural Background	Alternative Objective	Natural Background	Alternative Objective	Natural Background	Alternative Objective
Stateline	7.1	6.4	8.3	7.5	9.2	8.3
Iron Gate	7.3	6.6	8.2	7.4	9.6	8.6
Shasta	7.1	6.4	8.1	7.3	9.7	8.7
Scott	7.7	6.9	8.1	7.3	9.7	8.7
Seiad	8.1	7.3	8.5	7.7	10.1	9.1
Trinity	8.0	7.2	8.4	7.6	10.2	9.2
Turwar	7.6	6.8	8.4	7.6	9.9	8.9

For this alternative, staff proposes that Table 3-1 of the Basin Plan be updated as follows:

- In the Middle Klamath River above Iron Gate Dam and including Iron Gate and Copco Reservoirs, the existing daily minimum objective of 7.0 mg/L should be replaced with a daily minimum objective of 6.4 mg/L. This is based on model output for the location at the Stateline. Similarly, the existing 50% lower limit of 10.0 mg/L should be replaced by a 50% lower limit of 8.3 mg/L.
- For the Klamath River mainstem below Iron Gate Dam, the existing daily minimum of 8.0 mg/L DO should be replaced with a daily minimum of 6.4 mg/L based on the model output for the confluence of the Shasta River with the Klamath River. Similarly, the existing 50% lower limit of 10.0 mg/L should be replaced with 50% lower limit of 8.7 mg/L.
- In the Lower Klamath River HA, the existing daily minimum of 8.0 mg/L should be replaced by a daily minimum of 6.8 mg/L based on model output for Turwar. Similarly, the existing 50% lower limit of 10.0 mg/L should be replaced by a 50% lower limit of 8.9 mg/L.

The purpose of this proposed alternative is retain the same level of protection provided by the existing DO objectives as contained in Table 3-1 of the Basin Plan. Though the proposed objectives are lower than the existing ones, the two are nonetheless equivalent because they both are based on background conditions, adjusted to allow for variation from natural background, and differ only in the manner in which they are applied. The existing Table 3-1 DO objectives should only be applied to data collected during day light hours while the proposed alternative objectives can be applied to data collected either during the day or night.

Staff concludes that the natural conditions baseline scenario model output provides a reasonable basis for updating the Table 3-1 DO objectives for the Klamath River mainstem. The data are representative of *natural* background conditions with an allowance for 10% variation from natural conditions, incidental, and/or uncontrollable anthropogenic effects in a similar manner elsewhere reflected in the Basin Plan.

1.2.3 Alternative 3: Percent Saturation

In analyzing the DO objectives contained in Table 3-1 for the purpose of determining their appropriateness for the Klamath River, staff has also assessed their appropriateness for the rest of the region. A Peer Review Draft Staff Report for the Revision of Dissolved Oxygen Water Quality Objectives (NCRWQCB 2009) proposes the revision of the existing DO objectives region wide. The proposed revisions include an update of the life cycle DO requirements and the elimination of Table 3-1 DO objectives to be replaced by percent saturation objectives for those basins unable to meet life cycle DO requirements due to natural conditions. Percent saturation based on natural temperatures is proposed as the tool for estimating background DO conditions, in lieu of site-specific concentration-based estimates, because very few of the other waterbodies in the region have sufficient data from which to estimate natural background conditions. To remain consistent with the approach proposed for the rest of the region, staff has considered percent saturation as a tool for estimating background conditions in the Klamath River mainstem, as well.

Dissolved oxygen in healthy streams and rivers approaches saturation, fluctuating slightly due to the natural processes associated with photosynthesis and decomposition (Deas and Orlob 1999). The range of fluctuation in saturation in such a system is generally defined as 80-100% (Hauer and Hill 2007; SFBRWQCB 2007; Moyle 2008).

There are numerous regions, states and countries that utilize percent saturation as a water quality criterion for DO. For example, the San Francisco Bay Regional Water Quality Control Board requires that the median DO concentration for any three consecutive months not be less than 80% of the DO content at saturation (SFBRWQCB 2007). It further states that in areas unaffected by waste discharges, a level of about 85% of oxygen saturation exists (SFBRWQCB 2007). Region 3 (Central Coast) requires that median values not fall below 85% saturation as a result of controllable water quality conditions (CCRWQCB 1994). Region 5 (Central Valley) requires that for those surface water bodies outside the legal boundaries of the Delta, the monthly median of the mean daily DO concentration shall not fall below 85% of saturation in the main water mass (CVRWQCB 2007). It further requires that for water bodies unable to meet concentration-based DO objectives due to natural conditions, DO must be maintained at or above 95% of saturation (CVWQCB 2007). Finally, Region 8 (Santa Ana) requires that waste discharges shall not cause the median DO concentration to fall below 85% of saturation (SARRWQCB 2008).

The State of Oregon applies a 90% saturation criterion in those COLD waterbodies unable to meet concentration-based limits due to conditions of barometric pressure, altitude and temperature, and 95% saturation in SPWN waterbodies under the same conditions. The Hoopa Valley Tribe applies a 90% saturation criterion under natural receiving water temperatures in those COLD and SPWN waterbodies unable to meet concentration-based limits due to natural conditions. The National Rivers Authority of England requires DO in their RE1 waterbodies (very high quality, suitable for all fisheries) to be at or above 80% of saturation (NRA 1994).

With only one exception (the Hoopa Valley Tribe), each of these saturation-related DO objectives are based on existing temperature conditions. This means that as temperatures increase due to loss of riparian cover or decreases in water volumes through diversion, compliance with the DO objective can be maintained despite a lowering in DO. The Hoopa Valley Tribe adopted a saturation-based DO objective for the portion of the Klamath River within the Hoopa Valley Indian Reservation, recognizing the important relationship between DO and temperature and requiring that the saturation-based objective be calculated based on an estimate of natural stream temperatures. By this method, an anthropogenic effect on temperature could impact DO compliance, depending on the ecological dynamics of the system in question. This ensures that the multiple and interconnected parameters describing a healthy system work together to determine when effects are harmful to water quality.

The Hoopa Valley Tribe's DO objective for the protection of the Klamath River within the Hoopa Valley Indian Reservation were derived in part from a preliminary draft Regional Water Board staff report describing staff's proposed revisions for DO in the North Coast Region. Zabinsky and Azevedo (2005) described both the concept of calculating percent saturation based on natural temperatures and the use of 90% as an appropriate criterion. Since 2005, staff has continued to research the issues associated with DO saturation and natural variation. This research has led staff to propose an 85% saturation criterion as appropriate for establishing the range of fluctuation expected in healthy, free-flowing rivers. Staff proposes 85% saturation as an estimate of background, instead of 90%, for a number of reasons:

1. 85% and 90% of saturation both fall within the range of saturation values (80-100%) expected to represent natural background.
2. ODEQ (1995) called a Technical Advisory Committee, chaired by Gary Chapman of USEPA, to review its water quality objectives for DO. The Technical Advisory Committee concluded that Oregon's former water quality criteria of 90% and 95% of saturation were too conservative because natural conditions in some streams will cause DO levels to fall below 90%. Staff is concerned that erroneous violations of the water quality standard if set at 90% would unnecessarily trigger regulatory response. This is particularly true in a basin such as the Klamath which is naturally productive and could reasonably experience fluctuations in DO saturation below 90%.
3. Davis (1975) demonstrated that few members of a salmonid population will show the effects of oxygen stress if DO is at or above 85% saturation at temperatures up to 20°C and 93% of saturation at temperatures up to 25°C, suggesting that a percent saturation less than 85% may cause harm at higher temperatures. Because of the threatened and endangered status of some salmonid species in the North Coast Region, staff believes it necessary to provide at least the protection afforded by 85% of saturation, recognizing that the Klamath River mainstem does not naturally provide *ideal* conditions at all times.
4. The daily minimum criterion in the Upper and Middle Klamath River HAs, as derived from the Klamath TMDL model natural conditions baseline scenario, is

6.4 mg/L. It is 6.5 mg/L as calculated using 85% saturation and natural temperatures. For the Lower Klamath River HA, the Klamath TMDL model natural conditions baseline scenario indicates a daily minimum criterion of 6.8 mg/L as does the calculation of 85% saturation at natural temperatures. This indicates that the two procedures result in a similar level of protection. Objectives based on percent saturation, however, better ensure than do concentration based statistically derived criteria that ambient DO closely follows the natural pattern of seasonal fluctuation. This may be particularly important in the early fall and late spring as the spawning and incubation period begins and ends, respectively.

To protect against the possibility that a saturation-based criterion might result in DO concentrations harmful to salmonids, staff recommend including a 6.0 mg/L backstop. Carter (2008 [included as Appendix 4 of the Staff Report]), in a review of the scientific literature associated with salmonids and DO, determined that salmonids will begin to avoid locations with DO less than 6.0 mg/L.

1.3 Proposed Revised Dissolved Oxygen Objective Alternative

Staff views Alternative 1 to be inappropriate for the Klamath River because of the discrepancies between modeled natural conditions and the life cycle requirements of salmonids. Staff views both Alternatives 2 and 3 to provide appropriate and comparable water quality protection for the Klamath River. But, staff proposes the adoption of Alternative 3 for three reasons.

First, greater attention is being drawn to the issue of global climate change and the effect it is having on water quality, now and into the future. One of the issues the Regional Water Board will have to contend with in the near future is how to restructure the Basin Plan in such a way as to acknowledge the environmental changes resulting from global climate change while ensuring protection of beneficial uses. Staff believes that DO objectives based on percent saturation provide more flexibility in this regard than do static concentration-based objectives. This is the case because DO saturation is a function of temperature, adjusting as temperature adjusts.

A saturation-based DO objective does not provide adequate protection of beneficial uses if based on existing temperature conditions, though; because, as temperatures increase the allowable DO will decrease without regard to cause. A saturation-based DO objective based on an estimate of *natural temperatures*, however, ensures that only natural phenomena are considered when calculating appropriate DO objectives by this method.

Second, the problems associated with the Table 3-1 DO objectives for the Klamath River also exist for the other named basins. They are based on the same data set, collected by grab during day light hours in the 1950s and 1960s. As such, all the DO objectives contained in Table 3-1 require updating. Yet, only the Klamath, Shasta, and Laguna de Santa Rosa have DO modeling output developed by or for the Regional Water Board suitable for the development of site-specific DO objectives, such as described in Alternative 2. As described in NCRWQCB 2009, staff intends to propose in the future the adoption of region-wide DO objectives, including saturation-based criteria for those basins unable to meet salmonid life cycle requirements due to natural conditions. To be consistent with this approach, staff proposes the adoption of an 85% saturation objective at natural temperatures for the Klamath River mainstem.

Third, the Hoopa Valley Tribe has already adopted a saturation-based criterion for the Klamath River. Staff proposes that the Regional Water Board similarly adopt a saturation-based criterion so as to maintain a consistent approach throughout the Klamath River mainstem in California.

The Hoopa Valley Tribe has adopted a 90% saturation criterion, rather than an 85% criterion. The Klamath River begins in the upper basin as a low gradient river in nutrient rich volcanic soils where elevated loads of nutrients and organic material are released to the water column and flow downstream. This fuels elevated algal growth throughout the upper basin with a concomitant diel fluctuation. But, as the gradient of the river steepens through the middle basin, the effects of algal growth and decomposition are less dramatic. As such, while an 85% saturation criterion is appropriate higher up in the watershed as a measure of natural diel fluctuation, a 90% saturation criterion is arguably appropriate lower in the watershed, such as near the confluence with the Trinity within the Hoopa Valley Indian Reservation.

1.4 Proposed Site-Specific Dissolved Oxygen Objective for the Klamath River in California

Staff proposes the adoption of basin plan language in which the Table 3-1 DO objectives for the Klamath River are eliminated and replaced by narrative language describing the calculation of DO objectives based on 85% saturation and an estimate of natural temperatures.

Proposed Basin Plan language is as follows:

"Site-specific dissolved oxygen water quality objectives for the Klamath River are derived by calculating the daily minimum dissolved oxygen necessary to maintain 85% saturation under site salinity, site atmospheric pressure, and natural receiving water temperatures[3]. In no event may controllable factors reduce the daily minimum DO below 6.0 mg/L."

[3] The natural temperatures estimated in the Klamath River TMDL are deemed appropriate for the purpose of calculating the daily minimum dissolved oxygen necessary to maintain 85% DO saturation.

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